Image Analysis of Rock Colour to Interpret Fossil Flow Features

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Rock sequences display variations in colour, some of which are related to past histories of the passage of reactive fluids. This is particularly the case in many redbed sandstones, where 'bleached' volumes often record the passage of reduced fluids – they are in effect fossil flow features. It would be of considerable interest to be able to interpret these features to indicate the processes of solute movement through heterogeneous rock masses, both from the point of view of understanding the history of the rock and its mineralization / demineralization, and from the point of view of developing further understanding of the movement of pollutants through heterogeneous porous media.

Recent work has indicated that, in UK Triassic Sandstones, colour is very closely related to iron content, even in relatively unbleached sections of the rock. Preliminary work on images of rock exposures using image analysis software indicates that it is possible to explore not only the obvious bleached zones, but also the more subtle patterns in the rest of the rock sequence. The change in colour will indicate the mass removed, and therefore provide an estimate of the solution flux through the rock. In some cases, as preliminary lab experiments have shown, flow directions can be determined.

The aim of this project is to develop this approach, determining what it can and cannot yield, including assessment of the importance of a range of assumptions that might be applied in the interpretation of processed images. This will involve both technique development (e.g. repeatability, lighting issues, factors influencing colour properties) and application approaches (analysis of images from outcrops, interpretation using reactive transport numerical modelling).

The project would suit a student with background in geoscience, computer science, engineering, or physics, with potential to develop skills in conceptual model development, lab experimentation, and application of numerical modelling.

Further Project Details

A simple basic example of the technique proposed is illustrated in Figure 1. Figure 1(a) shows a section along the long axis of a 3 cm diameter core through which a reacting tracer solution has been passed from left to right for a limited time. The tracer changed the rock colour (appearing darkest grey on the image), and the image has been processed three times to locate zones where intensity is greater than three chosen thresholds, the latter decreasing left to right (red zones). Assuming that the greater the colour change the more pore volumes have passed through, and noting that greater pore volumes will be seen for distances closer to the source, intensity change in this case should reflect movement, as indeed it does. In Figure 1(b) the same approach has been used to process a field image of a sandstone exposure. The image on the left has a higher intensity threshold than the one on the right, indicating in analogy with the laboratory core the pattern of breakthrough: the patterns developed could be interpreted to indicate a complex of decimetre-scale channelled breakthroughs that eventually coalesce into tabular zones of solute movement. Clearly these interpretations rely on various assumptions, and exploring and developing ideas for circumventing these assumptions will an important part of the project.

It is envisaged that the main project components would include the following:

1. literature review of previous work on bleaching in sandstones and on colour in rock;
2. laboratory investigation of the factors controlling colour in the sandstones chosen for investigation;
3. laboratory investigation of the passage of reacting, colour-changing fluids through sandstone;
4. development of image analysis techniques to capture the information obtained from the images from the laboratory experiments of 3;
5. development of appropriate photographic techniques for obtaining images in the field (especially lighting conditions);
6. collection of images from 3D field exposures using the methods developed in 5;
7. processing of images using the techniques developed and validated in 4;
8. interpretation of the 4D information obtained using numerical modelling;
9. reporting (conference attendance, publishing of papers, thesis writing).

(a)

(b)

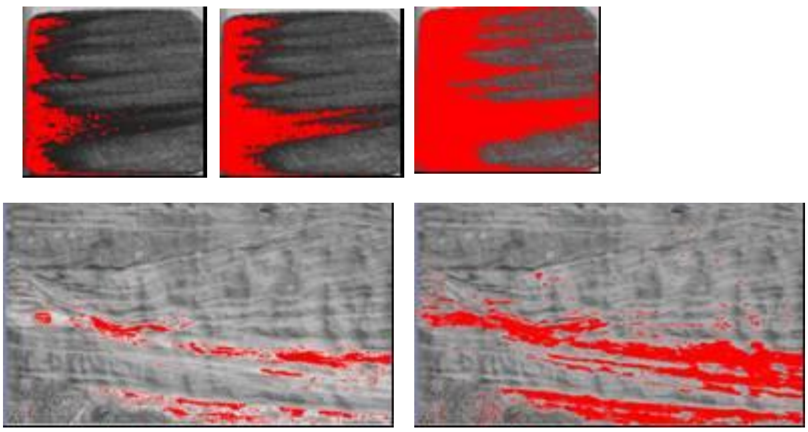

Figure 1: (a) Results of simple image analysis procedures carried out on a single image of a 3cm diameter core, sectioned along its long axis, through which a sorbing, colour-changing solute had been injected from the left continuously for a limited period of time. (b) An image of a field exposure (height about 1m) similarly interpreted, suggesting multi-point breakthrough but a tendency for flow towards the observer and to the left. In both (a) and (b), red indicates regions where intensity is greater than a specific threshold.

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